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United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Biological Resources Division

Midcontinent Ecological Science Center
4512 McMurry Avenue
Fort Collins, Colorado 80525-3400

August 26, 1998

Charley Chandler
U.S. Fish and Wildlife Service
Division of Environmental Contaminants
4401 North Fairfax Dr., MS 330
Arlington, VA 22203

Dear Charley,

Please find enclosed a copy of the report that you recently requested. The report is entitled "Testing Air Quality Monitoring Methods in the Alaska Maritime National Wildlife Refuge's Tuxedni Wilderness Area (Chisik Island)." The study was one of several pilot projects initiated in 1993 as part of the Biomonitoring of Environmental Status and Trends (BEST) Program. This project, along with the others initiated in 1993, was supported solely with BEST funding.

If you have any questions about this or other BEST projects, please contact me at (970) 226-9484.

Sincerely,

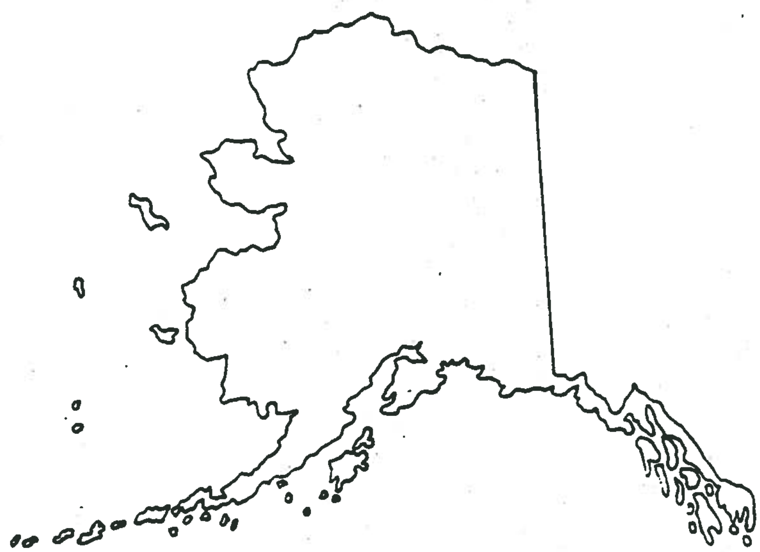
Jim

Jim Coyle
Biologist, BEST Program

Enclosure

Biomonitoring of Environmental Status and Trends Program

Testing Air Quality Monitoring Methods in the Alaska Maritime National Wildlife Refuge's Tuxedni Wilderness Area (Chisik Island)



National Biological Service
Ecosystem Monitoring Division
Washington, D.C.

BEST
BIOMONITORING of ENVIRONMENTAL STATUS and TRENDS

National Biological Service
Biomonitoring of Environmental Status and Trends Program

DRAFT
Pilot Project Report

Testing Air Quality Monitoring Methods in the Alaska Maritime National Wildlife Refuge's Tuxedni Wilderness Area (Chisik Island)

Prepared by:
Wayne Crayton
BEST Program Field Coordinator
Anchorage, Alaska

June 1995

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INTRODUCTION

Overview of BEST

The Biomonitoring of Environmental Status and Trends (BEST) Program of the National Biological Service (NBS) is a long-term, nationwide monitoring program intended to identify and understand the effects of environmental contaminants on biological resources. One component of BEST is specifically focussed on assessing contaminant threats to lands under the stewardship of the Department of the Interior. The second component of BEST focuses on describing the status and trends of contaminant effects on biological populations and the ecosystems that support them. Essential to the program's success is the identification, development and use of scientifically valid biomonitoring methods. Such methods will generate quality information that will be used by decision-makers and the public to guide local, regional and national conservation efforts.

Pilot Project Process and Objectives

This pilot addresses selected aspects of the BEST Program's overall Pilot Strategy: data collection (i.e., the suitability and effectiveness of selected field and laboratory methods) and data interpretation. Specifically, the pilot addresses 1993 Pilot Project Objective 2 [i.e., testing core methods which assist defining habitat quality on U.S. Fish and Wildlife Service (USFWS) lands].

The objectives of this pilot study are as follows:

1. Determine the feasibility of using selected lichens and mosses as air quality monitoring organisms in the arctic environment.

2. Determine the feasibility of using semipermeable membrane devices (SPMD) as a method for monitoring air quality in the arctic environment.

In addition to addressing BEST's needs, this pilot assists the USFWS with its responsibility to protect air quality-related values in Class I wilderness areas as requested by the Director, USFWS (cf. Memorandum from Director to Regional Directors, Regions 1-8, dated 17 January 1992; Subject: Air Quality Program). An earlier General Accounting Office review of wilderness areas managed by the USFWS stated that the USFWS "did not have a complete inventory of air quality-related values in any of its Class I areas" (General Accounting Office 1990). In addition, the GAO report noted that the permit review process was hampered by lack of data; this study will identify BEST's value by attempting to help rectify the problem by providing meaningful information to base management decisions upon.

BACKGROUND

U.S. Department of the Interior lands in Alaska are more likely to be contaminated by airborne contaminants rather than by contaminated surface waters and sediment transport mechanisms. For the aforementioned reasons, it is essential that BEST include methods designed to monitor (i.e. detect and measure) air quality-related impacts. The combined use of lichen/moss analyses and SPMDs may prove useful as air quality screening tools. Where found in sufficient quantity, lichens and mosses can be an ideal biological assay material for monitoring changes in plant tissue metal levels brought about by changing atmospheric chemistry (Barkman 1958, Ferry et al. 1973, Gilbert 1973, Martin and Coughtrey 1982). The establishment of element and nonpolar baselines at this time means that future collections will have a point of reference against which the magnitude and significance of change can be judged.

Semipermeable membrane devices have been shown to hold considerable promise in their ability to provide time-integrated concentrations of nonpolar organics in aquatic environments, and estimate bioavailability and potential bioconcentration factors for contaminants in organisms (Huckins et al. 1993). The feasibility of the SPMD approach for *in situ* monitoring of airborne contaminants also appears promising, as the SPMDs mimic the uptake of contaminants via the respiration process (Petty, et al. 1993).

STUDY AREA

The Alaska Maritime National Wildlife Refuge's Tuxedni Wilderness area (specifically Chisik Island) was chosen as a study area for significant reasons. Located within Tuxedni Bay on the western shore of lower Cook Inlet, the Tuxedni Wilderness area is a Class I air quality area which requires that stringent air quality standards be met (Clean Air Act, 42 U.S. Code 7401 et seq.) (Plate 1). The Act specifically protects Class I areas against significant deterioration; however, the Tuxedni Wilderness area lies within the energy-rich Kenai region and is about 50 miles southwest of increased activities (Plate 2) that are related to oil and natural-gas extraction, refinement, transportation, and combustion that potentially threaten the pristine nature of the wilderness area. Because prevailing winds are from the north and northeast, pollutants may be dispersed to the southwest into the Tuxedni Wilderness Area.

Chisik Island (latitude, 60° 06-10'N; longitude 152° 33-38'W; Kenai 1:250000 USGS quadrangle) encompasses an area of approximately 5,714 acres. The island is elongated with a north-south orientation and length of approximately 6 miles. The northernmost end is about 2.5 miles wide and tapers to about one-quarter mile wide at its southernmost tip. The topography of Chisik Island is rugged. The island's principle landscape feature is a steep plateau with an overall southeasterly dip of about 15 percent and an abrupt escarpment along its perimeter. Elevation of the plateau ranges from about 100 feet on the southern tip to about 2,674 feet in the north. The island has long, cool winters and short, cool summers.

Chisik Island is separated from the mainland by Tuxedni Channel which ranges in width from 0.5 miles at its southern end and 2.5 miles at its northern end.

Vegetation on Chisik Island is dominated by *Alnus crispa* thickets with an understory of grasses and ferns. Talbot et al. (1992) distinguished three broad zones within the vegetation of the Tuxedni Wilderness Area: (1) forest communities of *Picea sitchensis* and *Populus trichocarpa* are major components of the lowlands; (2) broadleaf deciduous *Alnus crispa* thickets predominate from lower to middle elevations, and (3) microphyllous evergreen *Empetrum nigrum-Cassiope stellerina* dwarf shrub heaths appear above approximately 1,900 feet.

Chisik Island (and neighboring Duck Island) provide nesting sites for about 28,000 black-legged kittiwakes *Rissa tridactyla*, 10,000 common murres *Uria aalge*, 6,000 · horned puffins *Fratercula corniculata* and smaller numbers of other sea and land birds, making it the largest seabird colony in Cook Inlet (Jones and Petersen, 1979). Little is known about the wildlife on Chisik Island. Moose and bear are rarely seen on the island. Small mammals (e.g. mice and shrews) are common. Beaver were introduced to the island but did not survive. Ptarmigan are common in the upland areas of the island.

METHODS

Because of the study area's remoteness and wilderness status, special permission was obtained from the USFWS to use helicopters and fixed wing aircraft to transport personnel and field equipment to where the SPMDs were deployed and lichen and moss were collected. Field work was conducted between June and August 1993.

Previous investigations of the lichen flora of the Tuxedni Wilderness area (Talbot et al. 1992) showed that fruticose lichens are most abundant in the alpine zone (above 2,000 ft). It was at this approximate elevation that ten samples of each of the following species were collected:

lichens - *Cladina rangiferina*; *Cladina stellaria*; *Cladonia uncialis*;
mosses - *Pseudoleskea baileyi; Rhytidiopsis robusta.*

Exact sampling locations were determined using a hand-held Global Positioning System (GPS) receiver and mapped using GIS capabilities (Plate 3).

Plants samples were collected using stainless-steel shears while wearing rubber gloves as a precaution against contamination from handling. Each plant sample consisted of about 50 grams of plant material and was stored in cloth bags and air dried. Samples were shipped to the Branch of Geochemistry, U.S. Geological Survey, Lakewood, Colorado, where they were washed using the method of Jackson et al. (1985). The cleaned material was oven dried at 40° C for 48 hours. Approximately 20 grams of material was then pulverized in a stainless steel blender and about 10 grams of dry, ground material was ashed in glass crucibles in a muffle furnace. Ashing occurred over a 22 hour period; the temperature was raised incrementally for the first 10 hours and then held at 500° C for 12 hours before being allowed to cool. Table 1 lists the methods used to determine the elemental concentrations in the collected lichen and moss samples.

Soils were examined in the field during June 21-28, 1993, with a shovel and hand auger and described by genetic horizon to a maximum depth of five feet. Holes were dug along transects that crossed each of the major map units and detailed soil descriptions were obtained. The relation of soils to vegetation and topography was observed along the transects and used to mark boundaries between soil map units on an aerial photograph. Site characteristics such as slope, slope length, drainage, landform, and vegetation were taken at each hole. Soil properties observed included color, texture, structure, root abundance and distribution, rock fragments, soil reaction, and horizon topography. Samples from 11 typical profiles were collected for comprehensive laboratory analysis.

Five 68-inch-long SPMDs were deployed on Chisik Island (elevation, 2,500 feet; latitude, 60° 09.453'N, longitude 152° 36.354'W) between June and July 1993 (Plate 3; Photograph 1). As a positive control, five SPMDs were deployed in metropolitan Anchorage (Photograph 2). Each SPMD contained two grams of neutral lipid and was suspended in the air for 28 days. Following retrieval, the SPMDs were shipped to the National Biological Service's Midwest Science Center where they were processed (i.e., dialyzed, subjected to high resolution gel permeation chromatographic cleanup and ampuled) and forwarded to the Mississippi State Chemical Laboratory (via the National Biological Service, Patuxent Analytical Control Facility) for analysis of nonpolar organic compounds. Performance evaluation materials (PEM), field blanks, a laboratory process blank and a SPMD control were analyzed as part of the quality control procedures sample set. The PEMs consisted of 30 ug of each priority pollutant PAH in 5mL of hexane and 10 ug of Aroclor 1242, 1248, 1254, and 1260 in 5mL hexane.

RESULTS AND DISCUSSION

The soil and vegetation information obtained during this pilot contributes to the necessary task of characterizing the study area. Site characterization quantifies biotic and abiotic factors so that changes in vegetation species and communities due to airborne contaminants can be reasonably separated from other environmental causes (Stolte et al., in USDA, 1993).

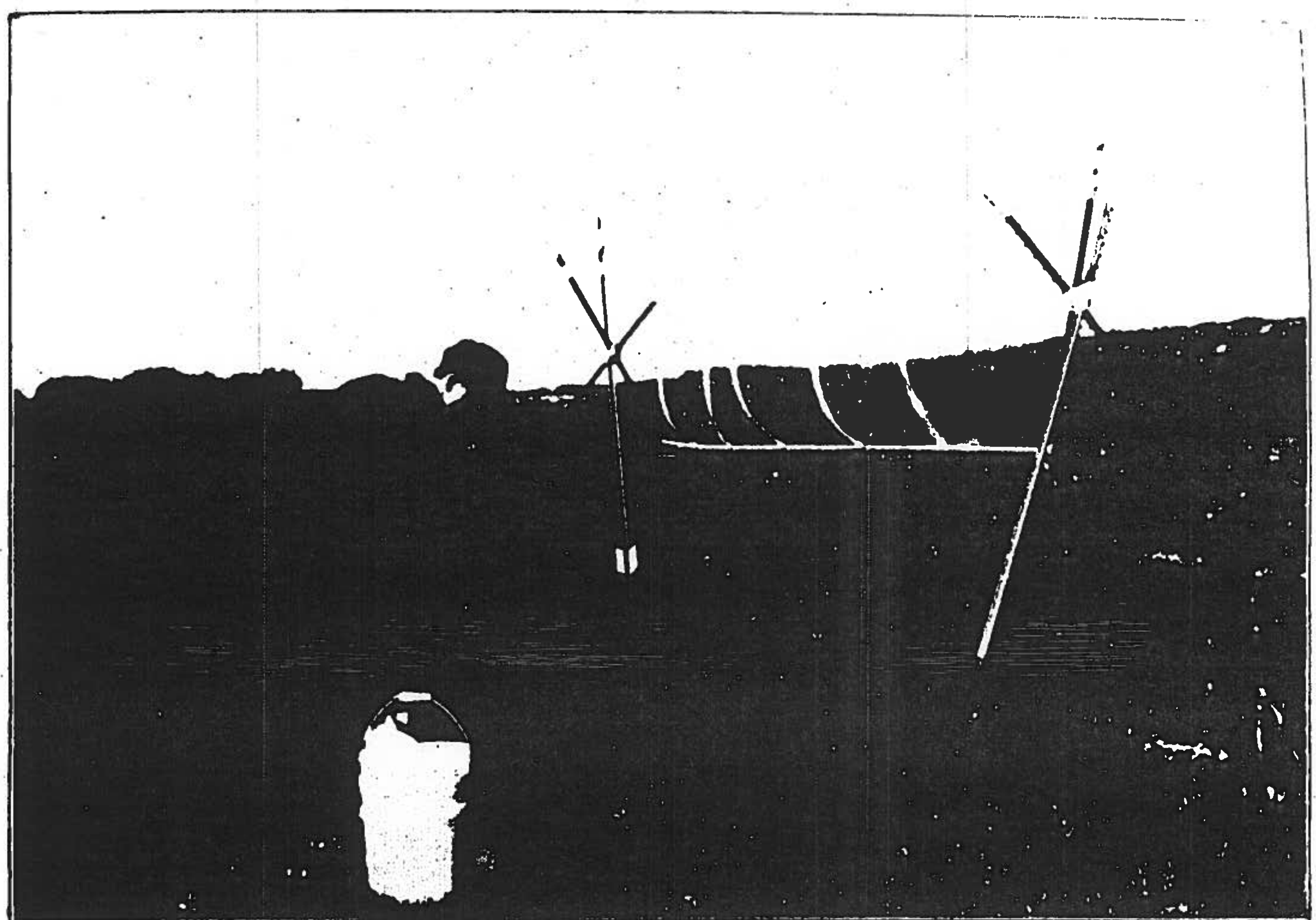
Vegetation and Soil Mapping

A total of 290 vascular plant species (279 native, 11 introduced) have been identified in the Tuxedni Wilderness Area (Appendix A). Several distinctive soil (Plate 4) and vegetation (Plate 5) relationships can be made for landforms (plateau, escarpments, alluvial fans, beach terraces) of the island (Appendix B). The primary study area lies on the island's broad

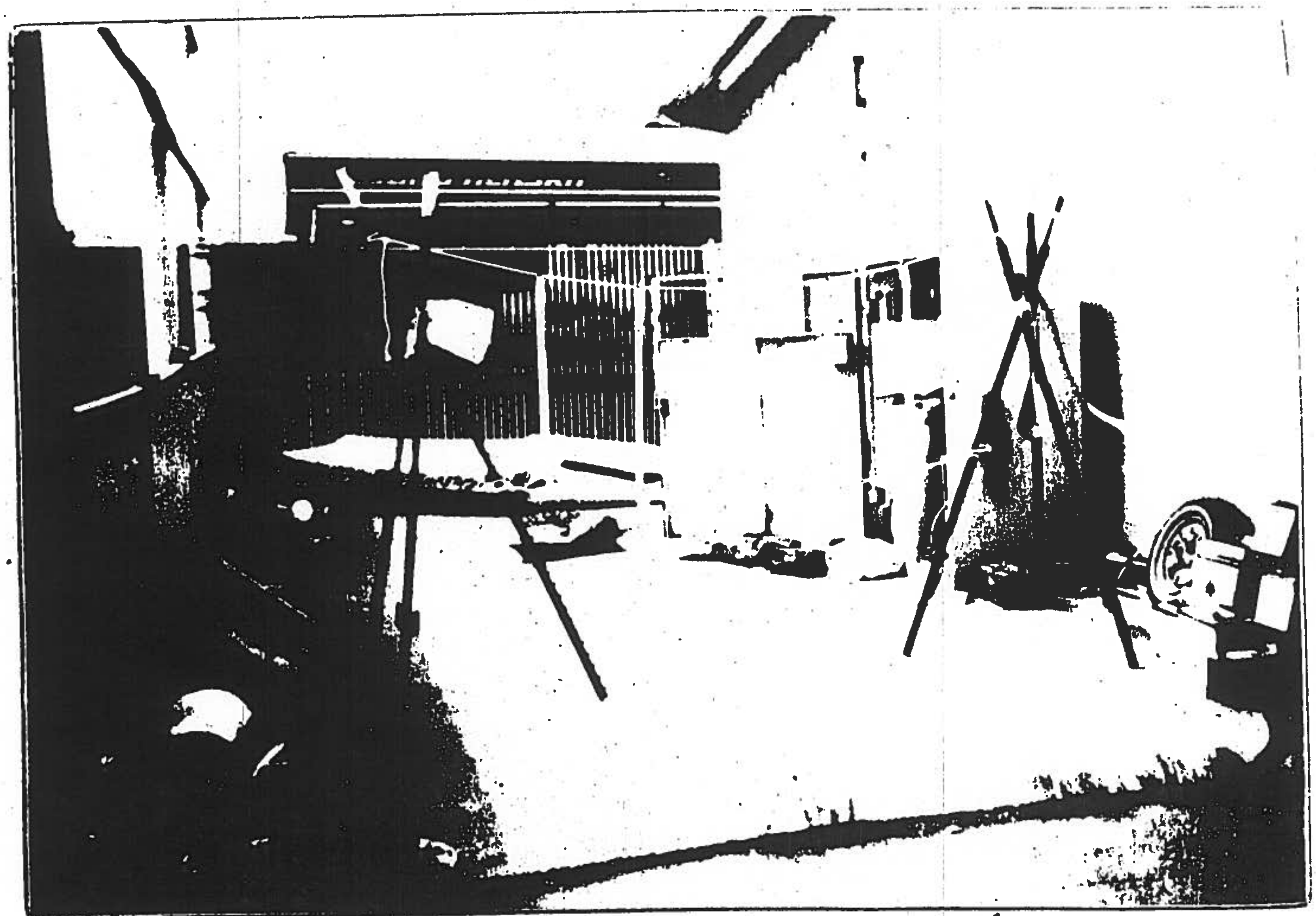
Table 1. Analytical methods used to determine elemental concentrations in collected lichen and moss samples collected from Chisik Island, June and July 1993.*

Analytical Method	Determination Limit	Variables
Continuous-flow hydride generation	0.1 ppm	As, Se
Inductively-coupled argon plasma optical emission spectroscopy	2.0 ppm	Ag, Cd, La, Li, Mo, Ni, Sc, Sr, V, Y
	0.05%	Al, Ca, Fe, K, Mg, Na, P, Ti
	1.0 ppm	Ba, Be, Co, Cr, Cu, Yb
	4.0 ppm	Ce, Ga, No, Mn, Nb, Nd, Pb, Th, Zn
	8.0 ppm	Au
	10.0 ppm	Bi
	20.0 ppm	Sn
	40.0 ppm	Ta
	100.0 ppm	U
Continuous-flow cold vapor	0.02 ppm	Hg
Combustion-IR	0.05%	S

* Analyses performed by the U.S. Geological Survey, Branch of Geochemistry, Lakewood, Colorado.



Photograph 1. SPMD deployment on Chisik Island.



Photograph 2. Spmd deployment in metropolitan Anchorage.

sloping plateau, which is the most extensive landform on the island and comprises about 75 percent of the land area. The plateau and subalpine plateau portions are mantled with volcanic ash and loess (i.e. fine-grained wind-deposited material, dominantly of silt size) about two to three feet thick over bedrock and occasionally glacial till. Alder scrub and mixed alder-salmonberry scrub vegetation dominate at lower elevations. Intermediate elevations have a more subalpine characteristic including large bluejoint grass-herbaceous meadows and Volcanic Ash Soils interspersed between areas of alder scrub and Dark Volcanic Ash Soils. Hummocky Alpine Soils, consisting of heath and willow hummocks, predominate above 1,900 feet. These features are a product of freezing and thawing. Shallow Alpine Soils occur adjacent to the plateau edge, have thin volcanic ash mantles that are typically less than 1.5 feet thick, and have lichen alpine tundra vegetation. Winter winds remove snow cover from these soils encouraging deep annual frost penetration and reducing effective precipitation. The lichen cover contributes little organic matter to the surface soil layers.

Soil, Lichen and Moss Chemical Analyses

Soil chemistry data (Appendix B) indicate that the shallow alpine soils (which support lichen and moss) are characteristic of high volcanic ash parent material which includes high organic carbon content, very high water capacities, high levels of phosphorus fixation and pH dependent cation exchange capacities.

Laboratory analysis of lichen and moss samples collected from Chisik Island's alpine tundra are summarized in Appendix C. Baseline information for the vegetation species was calculated on the dry-weight basis. In general, element concentration levels follow the progression: lichen < mosses. Thirty-two elements were detected in moss samples while 28 were detected in lichen samples. All element concentrations in lichens are particularly low compared to reported values (Crock et al. 1992). Moss concentrations, although continually higher than lichen concentrations, are not representative of an area adversely impacted by contaminated airborne particulates. However, one copper value (68 ppm) reported in a single moss sample is considered high and indicative of an area possibly influenced by airborne contaminants.

Since lichens lack stomata and have no control over gas exchange, they are responsive to changes in their physical and chemical environments. There is also some evidence that lichens respond to changes in their host substrates (Prussia and Killingbeck 1991). Wetmore (1983) suggests that a preliminary indication can be obtained for the air quality of an area by studying the lichens present in an area with reference to their sensitivity to sulfur dioxide. Twenty-one species of lichen on Chisik Island have been categorized in 5 sulfur dioxide-related sensitivity classes (Talbot, 1988): Only one, (*Cladina stellaria*), was chemically analyzed in this pilot. Based on the small sample size in this pilot, preliminary evidence indicates that there is no adverse air quality (SO_2) impact on Chisik Island, which is supported by previous studies conducted on the island (Talbot, 1988).

Semipermeable Membrane Devices

Quality Control Samples:

The results of the quality control samples, as determined by the contract laboratory are summarized in Appendix D (Tables 1 and 2). In general the results are acceptable. The value of Aroclor 1248 is somewhat high (130% recovery) but permissible. In the case of the PAHs, the reported values are acceptable. With the exception of HCB (which is a MSC laboratory contaminant, no blank sample contained residue greater than the stated detection limits of the contract laboratory (i.e. 0.25 uh/g for PAHs and 0.004 ug/g for PCBs and OCs. Based upon the results of the analysis of PEMs and the blanks, we believe the samples were deployed, retrieved, processed, and analyzed without introducing extraneous contamination. Consequently, the SPMD sample data appear to be representative and acceptable.

Field SPMD Samples:

The analysis of the five SPMD samples from Chisik Island revealed anthropogenetic contaminants to be present in only one sample. The residues; benzo(a)pyrene (0.35 ug), benzo(b)fluoranthene (0.28 ug), benzo(e)pyrene (0.30 ug), benzo(k)fluoranthene (0.30 ug), and perylene (0.39 ug) were all very low and near the stated detection limit. Consequently, the Chisik Island site does not appear to have been impacted by PAHs or other anthropogenic contaminants during the exposure period. In contrast to the Chisik Island site, contaminant residues were present in all five SPMD samplers located in Anchorage (Appendix D, Table 3). Alpha-BHC and gamma-BHC were present in four of five samplers with a mean value of 0.010 ug/SPMD and 0.017 ug/SPMD, respectively. No PCB residues were detected in these samplers. The PAH values presented three are somewhat variable but appear to verify the presence of PAH residues. Moreover, the residue found in these SPMDs are indicative of bioavailable residues (i.e. by respiration).

CONCLUSIONS

This project facilitated a partnership between USFWS efforts to document the botanical resources of Chisik Island and establish an analytical chemistry baseline in local lichen/moss communities for future reference and BEST Program efforts to identify potential methods for monitoring the presence and effects of airborne contaminants. In addition, a comprehensive soil and vegetation inventory of Chisik Island was performed in cooperation with the USDA's Natural Resources Conservation Service, U.S. Geological Survey and USFWS.

Semipermeable membrane device data demonstrate their utility to sequester airborne anthropogenic contaminants. Further, the SPMDs were successfully used to define the absence of detectable airborne contaminants on Chisik Island and the presence of typical anthropogenic contaminants in the air at the Anchorage site. Thus, the SPMD technique can be employed in ambient air monitoring activities. Further research is required to develop the algorithm(s) necessary to estimate actual air concentrations. This research would involve controlling laboratory studies to define the kinetics of uptake of contaminants by SPMDs and additional field deployment of the SPMDs.

The lichen/moss analytical data and soil chemistry profiles provide a valuable baseline for future comparisons. When sufficient data is available, this baseline data can be compared with more current data to determine whether correlations exist between data patterns and non-pollution physical and biological factors. Such correlations may provide a basis for determining to what extent these factors (i.e. elemental content and soil chemistry) influence lichen species diversity, distribution and abundance. Regression analyses might be used for studying trends over time and space. If the appropriate experimental design is used and the statistical assumptions are met, various parametric or non-parametric univariate approaches may be useful as well. The ultimate challenge for the BEST Program in establishing an air quality monitoring component is developing the capability to economically collect and interpret site characterization data and distinguish data patterns that can be attributed to airborne contaminants.

ACKNOWLEDGMENTS

This pilot study represents the cooperative effort of staff from the National Biological Service, U.S. Fish and Wildlife Service, U.S. Soil Conservation Service, and U.S. Geological Survey. Steve Talbot's (USFWS, Refuges and Wildlife, Anchorage, AK) botanical expertise and overall enthusiasm for this pilot study was critical and greatly appreciated. Mark Clark (USDA, Natural Resources Conservation Service, Palmer, AK) conducted the soil investigation and prepared a final report which will be used for future assessments. Tom Jennings (USFWS, Habitat Conservation, Anchorage, AK) provided geographical information system assistance, advice, and provided the report's color plates. Jim Crock (USGS, Geophysical Branch, Lakewood, Colorado) chemically analyzed the lichen and moss samples and tabulated the data. Special thanks are extended to Jim Petty (NBS, Midwest Science Center, Columbia, MO) for his advice, assistance, and final report on the possible use of semipermeable membrane devices in air quality monitoring studies. Nancy Tileston (USFWS, Librarian, Anchorage, AK) was very instrumental in obtaining difficult-to-find references. And finally, I thank John Martin (USFWS, Alaska Maritime National Wildlife Refuge) for allowing us to use helicopters on Chisik Island to transport gear and personnel to what would be otherwise inaccessible locations.

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Appendix A

Botanical Reconnaissance
of Tuxedni Wilderness Area, Alaska

Steve Talbot
U.S. Fish and Wildlife Service
Refuges and Wildlife
Anchorage, Alaska

abstract
only

BOTANICAL RECONNAISSANCE OF TUXEDNI WILDERNESS AREA, ALASKA

Stephen S. Talbot[1], Sandra Looman Talbot[1], and Stanley L. Welsh[2]

ABSTRACT. -- The vascular flora of two small maritime islands, Chisik and Duck Island (2,302 ha), comprising Tuxedni Wilderness located in western lower Cook Inlet, Alaska, was recorded to determine species composition in an area where few previous collections had been reported. The field study was conducted from sites selected to represent the totality of environmental variation within Tuxedni Wilderness. Data were analyzed using published reports to compare the vascular plant distribution pattern of Tuxedni with the northern hemisphere, North America, and Alaska..

A total of 290 species were identified, 279 native and 11 introduced. The annotated list of species for Tuxedni Wilderness expands the known range for many species filling a distribution gap within Hultén's Central Pacific Coast district.

---

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Anchorage, Alaska 99503

[2] Life Science Museum and Department of Botany and Range Science
Brigham Young University
Provo, Utah 84602

Compared with vascular plant distribution in the northern hemisphere, the flora of Tuxedni Wilderness primarily includes species of circumpolar (36.6 percent), eastern Asian (22.9) and North American (20.4) distribution. The most important longitudinal distributional classes within North America consist of transcontinental species (59.9 percent) and species restricted to the extreme west (32.2). The distribution of Tuxedni species in latitudinal zones peaks in the high- and low-subarctic, gradually decreasing through the low- to high-arctic. Latitudinal zone comparison based on the Raunkiaer life-form spectrum suggests the Tuxedni flora is closest to the high subarctic zone.

Appendix B

Soil Survey Investigation

Mark Clark and Chein-Lu Ping
U.S. Department of Agriculture
Natural Resources Conservation Service
University of Alaska Fairbanks
Palmer, Alaska

Table of contents only

SOIL SURVEY INVESTIGATION

Chisik Island
Tuxedni Wilderness Area
Alaska

by
Mark H. Clark
Chien-Lu Ping
USDA - Natural Resources Conservation Service
University of Alaska Fairbanks

June 1995

Foreword

This report describes the soils of Chisik Island, Tuxedni Wilderness Area, and provides information on their genesis and landscape setting. The soils investigation was requested by The United States Fish and Wildlife Service to complete the soils portion of a comprehensive soil and vegetation inventory.

The report contains a detailed soil map of the island at a scale of 1:24,000. Soil map unit descriptions and management information are in the section Soil Map Units. Complete descriptions of representative soil profiles, their classification, and a discussion of their formation are in the Formation of the Soils section and Appendix B.

Some terms used in this report have a special meaning in soil science and are defined in the glossary.

State Conservationist

Steven A. Probst
State Conservationist
Soil Conservation Service

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Appendix C

Analytical chemistry data sheets for collected lichen and moss samples.

Jim Crock
U.S. Geological Survey
Geochemistry Branch
Lakewood, Colorado

Appendix C. Elemental concentrations in moss samples from Chisik Island, June 1993.*

Sample ID	Lab #	Al, ppm	Ca, ppm	Fe, ppm	K, ppm	Mg, ppm	Na, ppm	P, ppm	Ti, ppm
PSEU BAI-8	555543	3100	6000	1400	2300	1500	850	850	110
PSEU BAI-D	555544	3900	6200	1500	1800	1600	1000	950	120
PSEU BAI-5	555545	3300	5800	1400	1300	1400	860	620	110
PSEU BAI-7	555546	2900	5200	1400	2200	1400	880	730	110
PSEU BAI-1	555547	3500	6800	1500	1600	1600	990	880	110
PSEU BAI-11	55554[illegible]	6100	6800	2400	2000	1800	1600	860	200
PSEU BAI-6	555549	4700	6400	1900	1900	1600	1200	810	150
RHYT ROB-1	555550	4500	7100	2000	2100	1800	1400	700	160
RHYT ROB-11	555551	6600	8500	2800	2400	1900	1900	970	210

Sample ID	Mn, ppm	Ba, ppm	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Ga, ppm	La, ppm	Li, ppm	Mo, ppm
PSEU BAI-8	120	65	1.6	1.1	1.1	12	0.7	0.9	0.6	<0.2
PSEU BAI-D	160	46	1.5	1.0	1.2	16	0.7	0.8	0.7	<0.2
PSEU BAI-5	120	39	1.5	0.9	1.1	11	0.5	0.8	0.6	<0.2
PSEU BAI-7	160	47	1.2	0.7	1.0	12	0.6	0.7	0.6	<0.2
PSEU BAI-1	170	62	1.6	0.9	1.2	20	0.7	0.9	0.7	0.2
PSEU BAI-11	200	68	2.5	1.6	1.6	15	1.1	1.4	1.0	<0.3
PSEU BAI-6	110	55	2.1	1.4	1.5	16	0.8	1.2	0.8	<0.2
RHYT ROB-1	260	70	1.6	1.0	1.6	24	0.9	0.9	0.9	<0.3
RHYT ROB-11	170	84	2.7	1.3	1.7	31	1.3	1.6	1.2	<0.4

Sample ID	Nb, ppm	Nd, ppm	Ni, ppm	Pb, ppm	Sc, ppm	Sr, ppm	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
PSEU BAI-8	<0.4	0.8	2.3	3.6	0.4	50	3.9	0.9	<0.1	21
PSEU BAI-D	0.5	0.5	2.9	5.2	0.5	47	4.3	0.8	<0.1	26
PSEU BAI-5	0.4	0.7	2.3	5.3	0.4	43	4.2	0.8	<0.1	21
PSEU BAI-7	0.5	0.5	1.7	3.2	0.4	42	4.2	0.7	<0.1	22
PSEU BAI-1	0.5	0.8	3.2	5.7	0.5	52	4.2	0.9	<0.1	28
PSEU BAI-11	0.6	1.0	2.3	5.5	0.7	60	6.9	1.3	<0.2	25
PSEU BAI-6	0.5	0.9	2.7	4.4	0.6	49	5.6	1.2	0.1	22
RHYT ROB-1	<0.6	0.7	3.2	3.7	0.6	55	5.5	0.9	<0.1	32
RHYT ROB-11	0.7	1.3	2.3	4.1	0.8	68	7.0	1.6	<0.2	32

Sample ID	As, ppm	Se, ppm	Hg, ppm	Total S, %	Ash, %
PSEU BAI-8	0.2	0.4	0.05	0.11	5.0
PSEU BAI-D	0.2	0.4	0.10	0.12	5.6
PSEU BAI-5	0.2	0.4	0.10	0.11	4.8
PSEU BAI-7	0.2	0.3	0.08	0.10	5.2
PSEU BAI-1	0.2	0.4	0.08	0.11	5.2
PSEU BAI-11	0.2	0.5	0.13	0.11	7.8
PSEU BAI-6	---	---	0.07	0.14	5.8
RHYT ROB-1	---	---	0.12	0.11	7.2
RHYT ROB-11	0.3	0.4	0.11	0.12	8.8

* ppm dry-weight basis

PSEU BAI - Pseudoleskea baileyi

RHYT ROB - Rhytidiopsis robusta

Appendix C. Elemental concentrations in moss samples from Chisik Island, June 1993.*

Sample ID	Lab #	Al, ppm	Ca, ppm	Fe, ppm	K, ppm	Mg, ppm	Na, ppm	P, ppm	Ti, ppm
RHYTROBU-A	555269	6800	9900	3200	2000	2300	2000	630	250
RHYTROBU-B	555270	6300	8200	2700	3300	2100	1700	900	210
RHYTROBU-C	555271	8000	7830	3200	2900	2100	1800	790	240
RHYTROBU-D	555272	6100	7200	3000	3100	2100	1700	770	230
RHYTROBU-5	555273	3900	7700	1700	2500	2000	1200	830	130
RHYTROBU-6	555274	5900	8680	2600	3600	2300	1600	1090	200
RHYTROBU-7	555275	4400	8600	1800	3300	2000	1200	990	150
RHYTROBU-8	555276	4700	6000	1800	2600	1500	1100	700	130
PSEUBAIL-A	555277	4900	6400	2200	2600	1700	1300	770	170
PSEUBAIL-B	555278	3900	6700	1600	2000	1800	1100	950	130
PSEUBAIL-C	555279	4300	5900	1700	1900	1600	1000	810	140

Sample ID	Mn, ppm	Ba, ppm	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Ga, ppm	La, ppm	Li, ppm	Mo, ppm
RHYTROBU-A	230	88	2.8	2.4	2.0	68	1.2	1.7	1.3	<0.3
RHYTROBU-B	260	76	2.7	2.4	1.7	15	1.2	1.6	1.2	<0.3
RHYTROBU-C	230	72	3.1	3.0	1.9	15	1.4	1.9	1.3	<0.3
RHYTROBU-D	180	66	2.2	1.4	2.2	11	1.2	1.3	1.2	<0.3
RHYTROBU-5	160	47	1.3	0.8	1.3	14	0.8	0.8	0.8	<0.2
RHYTROBU-6	400	86	2.1	1.6	1.9	14	1.2	1.3	1.0	<0.3
RHYTROBU-7	400	73	1.6	1.6	1.2	15	0.8	1.0	0.9	<0.2
RHYTROBU-8	120	64	1.9	1.5	1.3	11	0.8	1.1	0.8	<0.2
PSEUBAIL-A	200	64	2.2	1.4	1.6	12	0.8	1.3	0.9	<0.2
PSEUBAIL-B	220	90	1.8	1.3	1.2	14	0.7	1.0	0.8	<0.2
PSEUBAIL-C	110	48	2.2	1.1	1.4	16	0.7	1.4	0.8	0.2

Sample ID	Nb, ppm	Nd, ppm	Ni, ppm	Pb, ppm	Sc, ppm	Sr, ppm	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
RHYTROBU-A	0.8	1.2	3.9	5.0	1.0	88	9.0	1.6	<0.2	32
RHYTROBU-B	<0.7	1.3	2.5	4.8	0.7	71	7.5	1.5	<0.2	26
RHYTROBU-C	<0.7	1.4	2.5	5.4	0.9	72	9.0	1.7	0.2	23
RHYTROBU-D	0.7	0.9	3.0	5.6	0.8	62	8.2	1.3	<0.2	25
RHYTROBU-5	<0.5	<0.5	2.1	4.4	0.5	52	4.7	0.8	<0.1	24
RHYTROBU-6	0.7	1.0	2.3	3.9	0.8	74	7.3	1.3	0.2	30
RHYTROBU-7	0.6	0.5	1.9	2.8	0.5	73	5.2	0.9	<0.1	32
RHYTROBU-8	<0.5	0.8	1.9	3.2	0.5	53	4.8	1.1	<0.1	17
PSEUBAIL-A	0.6	1.1	2.6	4.2	0.6	52	6.2	1.2	0.1	24
PSEUBAIL-B	0.5	0.8	4.1	5.6	0.5	62	4.7	1.0	0.1	30
PSEUBAIL-C	0.6	1.0	2.3	5.4	0.5	49	4.7	1.2	<0.1	21

Sample ID	As, ppm	Se, ppm	Hg, ppm	Total S, %	Ash, %
RHYTROBU-A	0.3	0.3	0.07	0.09	9.0
RHYTROBU-B	0.2	0.4	0.06	0.11	8.2
RHYTROBU-C	0.3	0.4	0.06	0.10	9.0
RHYTROBU-D	0.3	0.4	0.07	0.10	8.2
RHYTROBU-5	---	---	0.06	0.10	6.4
RHYTROBU-6	0.2	0.3	0.04	0.12	7.8
RHYTROBU-7	0.2	0.3	0.04	0.12	6.6
RHYTROBU-8	0.2	0.3	0.04	0.10	7.0
PSEUBAIL-A	0.2	0.4	0.05	0.11	6.4
PSEUBAIL-B	0.2	0.4	0.06	0.11	5.6
PSEUBAIL-C	1.9	0.5	0.05	0.13	5.4

* ppm dry-weight basis
PSEUBAIL - *Pseudoleskea baileyi*
RHYTROBU - *Rhytidiopsis robusta*

Appendix C. Elemental concentrations in moss samples from Chisik Island, June 1993.*

Sample ID	Lab #	Al, %	Ca, %	Fe, %	K, %	Mg, %	Na, %	P, %	Ti, %
PSEU BAI-8	555543	6.1	12	2.8	4.5	3.0	1.7	1.7	0.21
PSEU BAI-D	555544	7.0	11	2.7	3.3	2.9	1.8	1.7	0.21
PSEU BAI-5	555545	6.8	12	3.0	2.8	3.0	1.8	1.3	0.23
PSEU BAI-7	55551[illegible]	5.6	10	2.7	[illegible].3	2.7	1.7	1.4	0.22
PSEU BAI-1	555547	6.8	13	2.9	3.1	3.0	1.9	1.7	0.22
PSEU BAI-11	555548	7.8	8.7	3.1	2.6	2.3	2.1	1.1	0.25
PSEU BAI-6	555549	8.1	11	3.3	3.1	2.7	2.0	1.4	0.26
RHYT ROB-1	555550	6.3	9.9	2.8	2.[illegible]	2.5	1.9	0.97	0.22
RHYT ROB-11	555551	7.5	9.7	3.2	2.7	2.2	2.2	1.1	0.24

Sample ID	Mn, ppm	Ba, ppm	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Ga, ppm	La, ppm	Li, ppm	Mo, ppm
PSEU BAI-8	2300	1300	31	22	22	240	13	17	12	<4
PSEU BAI-D	2900	830	26	17	22	280	13	15	13	<4
PSEU BAI-5	2600	810	31	18	23	220	11	17	13	<4
PSEU BAI-7	3100	910	23	14	20	230	12	13	12	<4
PSEU BAI-1	3200	1200	31	18	23	380	13	18	13	4
PSEU BAI-11	2600	870	32	21	20	190	14	18	13	<4
PSEU BAI-6	1900	940	36	24	26	280	13	21	14	<4
RHYT ROB-1	3600	970	22	14	22	330	13	13	13	<4
RHYT ROB-11	1900	960	31	15	19	350	15	18	14	<4

Sample ID	Nb, ppm	Nd, ppm	Ni, ppm	Pb, ppm	Sc, ppm	Sr, ppm	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
PSEU BAI-8	<8	16	45	71	8	990	78	17	<2	420
PSEU BAI-D	8	9	52	92	8	840	77	15	<2	460
PSEU BAI-5	9	15	47	110	9	900	88	17	<2	440
PSEU BAI-7	9	10	33	61	8	800	81	13	<2	430
PSEU BAI-1	9	16	62	110	9	1000	81	17	<2	540
PSEU BAI-11	8	13	29	70	9	770	88	17	<2	320
PSEU BAI-6	8	15	47	76	11	850	96	20	2	380
RHYT ROB-1	<8	9	45	52	8	770	77	13	<2	450
RHYT ROB-11	8	15	26	46	9	770	79	18	<2	360

Sample ID	As, ppm	Se, ppm	Hg, ppm	Total S, %	Ash, %
PSEU BAI-8	0.2	0.4	0.05	0.11	5.0
PSEU BAI-D	0.2	0.4	0.10	0.12	5.6
PSEU BAI-5	0.2	0.4	0.10	0.11	4.8
PSEU BAI-7	0.2	0.3	0.08	0.10	5.2
PSEU BAI-1	0.2	0.4	0.08	0.11	5.2
PSEU BAI-11	0.2	0.5	0.13	0.11	7.8
PSEU BAI-6	---	---	0.07	0.14	5.8
RHYT ROB-1	---	---	0.12	0.11	7.2
RHYT ROB-11	0.3	0.4	0.11	0.12	8.8

* determined on raw material, ash basis data
PSEUBAI - Pseudoleska baileyi
RHYTROB - Rhytidiopsis robusta

Appendix C. Elemental concentrations in moss samples from Chisik Island, June 1993.*

Sample ID	Lab #	AL, %	Ca, %	Fe, %	K, %	Mg, %	Na, %	P, %	Ti, %
RHYTROBU-A	555269	7.5	11	3.5	2.2	2.5	2.2	0.70	0.28
RHYTROBU-B	555270	7.7	10	3.3	4.0	2.6	2.1	1.1	0.26
RHYTROBU-C	555271	8.9	8.7	3.5	3.2	2.3	2.0	0.88	0.27
RHYTROBU-D	555272	7.4	8.8	3.6	3.8	2.5	2.1	0.94	0.28
RHYTROBU-5	555273	6.1	12	2.6	3.9	3.1	1.8	1.3	0.21
RHYTROBU-6	555274	7.5	11	3.3	4.6	2.9	2.0	1.4	0.26
RHYTROBU-7	555275	6.7	13	2.8	5.0	3.1	1.8	1.5	0.22
RHYTROBU-8	555276	6.7	8.6	2.5	3.7	2.2	1.6	1.0	0.19
PSEUBAIL-A	555277	7.7	10	3.4	4.0	2.6	2.0	1.2	0.26
PSEUBAIL-B	555278	7.0	12	2.9	3.5	3.2	2.0	1.7	0.23
PSEUBAIL-C	555279	7.9	11	3.1	3.6	2.9	1.9	1.5	0.25

Sample ID	Mn, ppm	Ba, ppm	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Ca, ppm	La, ppm	Li, ppm	Mo, ppm
RHYTROBU-A	2500	980	31	27	22	750	13	19	14	<4
RHYTROBU-B	3200	930	33	29	21	180	14	19	14	<4
RHYTROBU-C	2500	800	34	33	21	170	15	21	14	<4
RHYTROBU-D	2200	800	27	17	27	140	14	16	15	<4
RHYTROBU-5	2500	730	20	13	20	220	12	12	12	<4
RHYTROBU-6	5100	1100	27	21	24	180	15	17	13	<4
RHYTROBU-7	6000	1100	24	24	18	220	12	15	13	<4
RHYTROBU-8	1700	920	27	22	18	150	11	16	11	<4
PSEUBAIL-A	3100	1000	35	22	22	190	13	21	14	<4
PSEUBAIL-B	3900	1600	32	23	21	250	12	18	14	<4
PSEUBAIL-C	2100	890	40	20	24	300	12	26	14	4

Sample ID	Nb, ppm	Nd, ppm	Ni, ppm	Pb, ppm	Sc, ppm	Sr, ppm	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
RHYTROBU-A	9	13	43	56	11	980	100	18	<2	360
RHYTROBU-B	<8	16	30	58	9	870	91	18	<2	320
RHYTROBU-C	<8	15	28	60	10	800	100	19	2	250
RHYTROBU-D	8	11	37	68	10	760	100	16	<2	310
RHYTROBU-5	<8	<8	32	69	8	820	74	12	<2	380
RHYTROBU-6	9	13	30	50	10	950	93	16	2	380
RHYTROBU-7	9	8	29	43	8	1100	79	14	<2	480
RHYTROBU-8	<8	12	27	45	7	750	69	15	<2	240
PSEUBAIL-A	9	17	41	66	10	820	97	19	2	380
PSEUBAIL-B	9	14	73	100	9	1100	83	17	2	530
PSEUBAIL-C	11	18	42	100	9	900	87	22	<2	390

Sample ID	As, ppm	Se, ppm	Hg, ppm	Total S, %	Ash, %
RHYTROBU-A	0.3	0.3	0.07	0.09	9.0
RHYTROBU-B	0.2	0.4	0.06	0.11	8.2
RHYTROBU-C	0.3	0.4	0.06	0.10	9.0
RHYTROBU-D	0.3	0.4	0.07	0.10	8.2
RHYTROBU-5	---	---	0.06	0.10	6.4
RHYTROBU-6	0.2	0.3	0.04	0.12	7.8
RHYTROBU-7	0.2	0.3	0.04	0.12	6.6
RHYTROBU-8	0.2	0.3	0.04	0.10	7.0
PSEUBAIL-A	0.2	0.4	0.05	0.11	6.4
PSEUBAIL-B	0.2	0.4	0.06	0.11	5.6
PSEUBAIL-C	1.9	0.5	0.05	0.13	5.4

* determined on raw material, ash basis data
PSEUBAIL - <u>Pseudoleska</u> <u>baileyi</u>
RHYTROBU - <u>Rhytidiopsis</u> <u>robusta</u>

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	Lab #	Al, ppm	Ca, ppm	Fe, ppm	K, ppm	Mg, ppm	Na, ppm	P, ppm	Ti, ppm
CLADRANG-1	555239	1700	2100	890	1100	720	570	370	79
CLADRANG-2	555240	690	1700	330	740	610	290	370	31
CLADRANG-3	555241	970	2100	430	950	660	380	400	40
CLADRANG-4	555242	1200	1500	620	940	580	470	360	52
CLADRANG-5	555243	1100	2100	490	1000	730	410	450	45
CLADRANG-7	555244	650	1400	290	850	550	280	370	28
CLADRANG-8	555245	1000	1300	470	810	460	400	280	40
CLADRANG-9	555246	1400	1800	660	870	620	540	310	60
CLADRANG-10	555247	1000	1400	430	870	500	410	340	35
CLADRANG-11	555248	850	1200	440	580	440	360	270	34
CLADSTEL-1	555249	650	1400	90	890	490	260	360	29
CLADSTEL-2	555250	580	1500	280	1000	550	280	500	24
CLADSTEL-3	555251	650	1300	300	960	480	280	380	29
CLADSTEL-4	555252	630	1200	280	770	420	270	360	27
CLADSTEL-5	555253	530	1400	240	920	520	230	370	24
CLADSTEL-7	555254	1200	980	530	1000	430	400	340	50
CLADSTEL-8	555255	390	960	180	870	370	200	390	17
CLADSTEL-9	555256	400	1000	200	930	420	200	370	18
CLADSTEL-10	555257	1000	1500	430	900	500	380	380	40
CLADSTEL-11	555258	530	1400	270	940	460	250	430	25
CLADUNCL-1	555259	640	1200	350	710	440	280	310	32
CLADUNCL-2	555260	590	1500	290	680	460	280	350	27
CLADUNCL-3	555261	550	1600	260	820	520	290	290	24
CLADUNCL-4	555262	630	1400	340	710	430	310	340	31
CLADUNCL-5	555263	930	1800	430	896	590	370	340	38
CLADUNCL-7	555264	800	1200	370	676	390	320	300	33
CLADUNCL-8	555265	800	1300	390	704	490	330	310	28
CLADUNCL-9	555266	640	2800	320	642	660	370	310	29
CLADUNCL-10	555267	1100	1400	520	935	500	450	380	42
CLADUNCL-11	555268	360	1500	190	585	450	250	290	17

* ppm dry-weight basis

CLADRANG - <u>Cladina rangiferina</u>
CLADSTEL - <u>Cladina stellaria</u>
CLADUNCL - <u>Cladonia unicialis</u>

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	As, ppm	Se, ppm	Hg, ppm	Total S, %	Ash, %
CLADRANG-1	0.10	0.10	0.02	<0.05	2.47
CLADRANG-2	0.10	0.10	0.03	<0.05	1.33
CLADRANG-3	0.10	0.10	0.02	<0.05	1.73
CLADRANG-4	0.10	0.20	0.03	<0.05	1.87
CLADRANG-5	0.10	0.10	0.02	0.05	1.87
CLADRANG-7	0.10	0.20	0.02	<0.05	1.20
CLADRANG-8	0.10	0.20	0.03	<0.05	1.47
CLADRANG-9	0.10	0.10	0.02	<0.05	2.07
CLADRANG-10	0.10	0.10	0.02	<0.05	1.53
CLADRANG-11	0.10	0.10	0.02	<0.05	1.27
CLADSTEL-1	----	----	0.02	0.05	1.20
CLADSTEL-2	0.10	0.30	0.02	0.05	1.27
CLADSTEL-3	0.10	0.30	0.02	0.05	1.20
CLADSTEL-4	0.10	0.30	0.02	0.05	1.13
CLADSTEL-5	0.10	0.30	0.02	0.05	1.13
CLADSTEL-7	0.10	0.40	0.03	0.06	1.60
CLADSTEL-8	<0.05	0.30	0.02	0.05	0.87
CLADSTEL-9	<0.05	0.40	0.02	0.05	0.93
CLADSTEL-10	0.10	0.30	0.03	0.05	1.53
CLADSTEL-11	0.05	0.30	0.05	0.06	1.13
CLADUNCL-1	0.10	0.10	0.05	<0.05	1.13
CLADUNCL-2	0.10	0.10	0.04	<0.05	1.13
CLADUNCL-3	----	----	0.04	<0.05	1.20
CLADUNCL-4	0.10	0.10	0.04	<0.05	1.13
CLADUNCL-5	0.10	0.10	0.04	<0.05	1.60
CLADUNCL-7	----	----	0.04	<0.05	1.23
CLADUNCL-8	0.10	0.10	0.04	<0.05	1.33
CLADUNCL-9	0.10	0.10	0.04	<0.05	1.53
CLADUNCL-10	0.10	0.10	0.03	<0.05	1.67
CLADUNCL-11	<0.05	0.10	0.04	<0.05	0.93

* ashed basis data

CLADRANG - *Cladina rangiferina*
CLADSTEL - *Cladina stellaria*
CLADUNCL - *Cladonia unicialis*

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	Mo, ppm	Nb, ppm	Nd, ppm	Ni, ppm	Pb, ppm	Sc, ppm	Sr, ppm	V, ppm	Y, ppm	Zn, ppm
CLADRANG-1	<4	8	9	18	27	12	620	120	15	520
CLADRANG-2	<4	<8	8	140	40	9	860	77	12	1800
CLADRANG-3	5	<8	10	20	29	8	830	77	12	930
CLADRANG-4	<4	<8	10	24	36	11	630	100	14	600
CLADRANG-5	4	<8	<8	20	29	9	760	78	12	880
CLADRANG-7	4	<8	8	32	48	9	870	72	12	1100
CLADRANG-8	5	<8	11	35	70	11	780	96	16	800
CLADR[illegible]NG-[illegible]	<4	8	9	18	[illegible]	10	700	98	13	660
CLADRANG-10	<4	<8	10	23	41	9	750	82	13	750
CLADRANG-11	6	<8	11	28	56	11	750	100	17	550
CLADSTEL-1	4	<8	12	[illegible]	45	9	810	79	18	1100
CLADSTEL-2	4	<8	<8	68	47	8	830	72	13	1100
CLADSTEL-3	4	<8	12	49	88	9	800	81	14	1200
CLADSTEL-4	4	<8	16	64	59	9	830	80	18	990
CLADSTEL-5	<4	<8	11	25	42	8	850	69	13	1300
CLADSTEL-7	<4	8	12	24	36	11	560	100	18	690
CLADSTEL-8	<4	<8	10	27	77	8	810	66	13	1200
CLADSTEL-9	5	<8	12	34	77	8	900	68	15	1000
CLADSTEL-10	<4	<8	20	26	84	10	820	83	19	920
CLADSTEL-11	5	<8	10	25	48	9	850	76	14	1200
CLADUNCL-1	<4	8	11	48	91	10	850	97	15	1000
CLADUNCL-2	<4	<8	11	28	61	9	900	77	13	1100
CLADUNCL-3	5	<8	8	36	55	7	940	67	11	1600
CLADUNCL-4	<4	<8	12	28	44	10	880	91	16	950
CLADUNCL-5	<4	<8	9	50	53	9	820	83	13	1300
CLADUNCL-7	<4	<8	11	32	82	10	790	89	15	980
CLADUNCL-8	<4	<8	14	62	62	9	850	90	16	1300
CLADUNCL-9	10	<8	<8	38	52	7	1300	61	10	1200
CLADUNCL-10	<4	<8	11	99	54	10	710	95	16	1100
CLADUNCL-11	13	<8	9	83	110	7	1200	61	13	940

* ashed basis data

CLADRANG - Cladina rangiferina
CLADSTEL - Cladina stellaria
CLADUNCL - Cladonia unicialis

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	Mn, ppm	Ba, ppm	Cd, ppm	Ce, ppm	Co, ppm	Cr, ppm	Cu ppm	Ga, ppm	La, ppm	Li, ppm
CLADRANG-1	2000	530	<4	21	15	27	130	15	14	18
CLADRANG-2	5400	550	<4	19	12	31	230	12	13	16
CLADRANG-3	2600	540	<4	17	11	22	190	12	13	15
CLADRANG-4	2200	610	<4	20	14	29	130	14	14	17
CLADRANG-5	2800	580	<4	19	11	22	180	15	12	15
CLADRANG-7	2600	660	<4	18	12	29	230	13	13	15
CLADRANG-8	1100	660	<4	25	13	35	170	15	16	18
CLADRANG-9	2100	700	<4	20	13	25	140	14	13	16
CLADRANG-10	1800	680	<4	20	13	26	160	14	13	16
CLADRANG-11	2300	710	<4	26	15	40	160	16	15	17
CLADSTEL-1	3700	480	<4	27	14	28	200	13	16	14
CLADSTEL-2	3700	490	<4	20	12	29	220	11	12	15
CLADSTEL-3	2600	540	<4	20	12	27	210	12	14	15
CLADSTEL-4	2200	570	4	28	13	28	330	12	16	15
CLADSTEL-5	4400	510	<4	20	11	27	260	11	12	14
CLADSTEL-7	1700	630	<4	25	13	26	150	14	16	17
CLADSTEL-8	2400	580	<4	20	11	25	270	10	12	13
CLADSTEL-9	1800	540	5	26	11	28	330	10	15	13
CLADSTEL-10	1400	630	<4	30	13	28	210	14	17	16
CLADSTEL-11	2500	590	<4	22	11	35	280	12	13	14
CLADUNCL-1	2700	530	<4	25	14	32	180	12	15	16
CLADUNCL-2	3300	590	<4	18	12	29	620	10	13	16
CLADUNCL-3	2600	490	<4	16	11	27	590	10	12	15
CLADUNCL-4	3000	580	<4	22	12	29	340	12	14	16
CLADUNCL-5	2600	500	<4	18	12	30	180	11	13	16
CLADUNCL-7	2000	620	<4	26	12	29	230	15	15	16
CLADUNCL-8	1600	630	<4	25	13	30	190	14	15	16
CLADUNCL-9	1100	620	<4	16	10	23	260	9	12	14
CLADUNCL-10	1900	650	<4	26	14	31	180	14	14	17
CLADUNCL-11	2900	620	<4	21	11	28	930	9	13	16

* ashed basis data

CLADRANG - *Cladina rangiferina*
CLADSTEL - *Cladina stellaria*
CLADUNCL - *Cladonia unicialis*

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	Lab #	Al, %	Ca, %	Fe, %	K, %	Mg, %	Na, %	P, %	Ti, %
CLADRANG-1	555239	7.0	8.5	3.6	4.3	2.9	2.3	1.5	0.32
CLADRANG-2	555240	5.2	13	2.5	5.6	4.6	2.2	2.8	0.23
CLADRANG-3	55 241	5.6	12	2.5	5.5	3.8	2.2	2.3	0.23
CLADRANG-4	555242	6.6	7.9	3.3	5.0	3.1	2.5	1.9	0.28
CLADRANG-5	555243	5.8	11	2.6	5.6	3.9	2.2	2.4	0.24
CLADRANG-7	555244	5.4	12	2.4	7.1	4.6	2.3	3.1	23
CLADRANG-8	555245	6.8	8.8	3.2	5.5	3.1	2.7	1.9	0.27
CLADRANG-9	555246	7.0	8.7	3.2	4.2	3.0	2.6	1.5	0.29
CLADRANG-10	555247	6.7	9.0	2.8	5.7	3.3	2.7	2.2	0.23
CLADRANG-11	555248	6.7	9.4	3.5	4.6	3.5	2.8	2.1	0.27
CLADSTEL-1	555249	5.4	12	2.4	7.4	4.1	2.2	3.0	0.24
CLADSTEL-2	555250	4.6	12	2.2	7.9	4.3	2.2	3.9	0.19
CLADSTEL-3	555251	5.4	11	2.5	8.0	4.0	2.3	3.2	0.24
CLADSTEL-4	555252	5.6	11	2.5	6.8	3.7	2.4	3.2	0.24
CLADSTEL-5	555253	4.7	12	2.1	8.1	4.6	2.0	3.3	0.21
CLADSTEL-7	555254	7.2	6.1	3.3	6.4	2.7	2.5	3.1	0.31
CLADSTEL-8	555255	4.5	11	2.1	10	4.2	2.3	4.5	0.20
CLADSTEL-9	555256	4.3	11	2.1	10	4.5	2.1	4.0	0.19
CLADSTEL-10	555257	6.7	9.5	2.8	5.9	3.3	2.5	2.5	0.26
CLADSTEL-11	555258	4.7	12	2.4	8.3	4.1	2.2	3.8	0.22
CLADUNCL-1	555259	5.7	11	3.1	6.3	3.9	2.5	2.7	0.28
CLADUNCL-2	555260	5.2	13	2.6	6.0	4.1	2.5	3.1	0.24
CLADUNCL-3	555261	4.6	13	2.2	6.8	4.3	2.4	2.4	0.20
CLADUNCL-4	555262	5.6	12	3.0	6.3	3.8	2.7	3.0	0.27
CLADUNCL-5	555263	5.8	11	2.7	5.6	3.7	2.3	2.1	0.24
CLADUNCL-7	555264	6.5	9.4	3.0	5.5	3.2	2.6	2.4	0.27
CLADUNCL-8	555265	6.0	10	2.9	5.3	3.7	2.5	2.3	0.21
CLADUNCL-9	555266	4.2	18	2.1	4.2	4.3	2.4	2.0	0.19
CLADUNCL-10	555267	6.6	8.5	3.1	5.6	3.0	2.7	2.3	0.25
CLADUNCL-11	555268	3.9	16	2.0	6.3	4.8	2.7	3.1	0.18

* ashed basis data

CLADRANG - <u>Cladina rangiferina</u>
CLADSTEL - <u>Cladina stellaria</u>
CLADUNCL - <u>Cladonia unicialis</u>

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	As, ppm	Se, ppm	Hg, ppm	Total S, %	Ash, %
CLADRANG-1	0.10	0.1	0.02	<0.05	2.47
CLADRANG-2	0.10	0.1	0.03	<0.05	1.33
CLADRANG-3	0.10	0.1	0.02	<0.05	1.73
CLADRANG-4	0.10	0.2	0.03	<0.05	1.87
CLADRANG-5	0.10	0.1	0.02	0.05	1.87
CLADRANG-7	0.10	0.2	0.02	<0.05	1.20
CLADRANG-8	0.10	0.2	0.03	<0.05	1.47
CLADRANG-9	0.10	0.1	0.02	<0.05	2.07
CLADRANG-10	0.10	0.1	0.02	<0.05	1.53
CLADRANG-11	0.10	0.1	0.02	<0.05	1.27
CLADSTEL-1	----	---	0.02	0.05	1.20
CLADSTEL-2	0.10	0.3	0.02	0.05	1.27
CLADSTEL-3	0.10	0.3	0.02	0.05	1.20
CLADSTEL-4	0.10	0.3	0.02	0.05	1.13
CLADSTEL-5	0.10	0.3	0.02	0.05	1.13
CLADSTEL-7	0.10	0.4	0.03	0.06	1.60
CLADSTEL-8	<0.05	0.3	0.02	0.05	0.87
CLADSTEL-9	<0.05	0.4	0.02	0.05	0.93
CLADSTEL-10	0.10	0.3	0.03	0.05	1.53
CLADSTEL-11	0.05	0.3	0.05	0.06	1.13
CLADUNCL-1	0.10	0.1	0.05	<0.05	1.13
CLADUNCL-2	0.10	0.1	0.04	<0.05	1.13
CLADUNCL-3	----	---	0.04	<0.05	1.20
CLADUNCL-4	0.10	0.1	0.04	<0.05	1.13
CLADUNCL-5	0.10	0.1	0.04	<0.05	1.60
CLADUNCL-7	----	---	0.04	<0.05	1.23
CLADUNCL-8	0.10	0.1	0.04	<0.05	1.33
CLADUNCL-9	0.[illegible]	0.1	0.04	<0.05	1.53
CLADUNCL-10	0.10	0.1	0.03	<0.05	1.67
CLADUNCL-11	<0.05	0.1	0.04	<0.05	0.93

* ppm dry-weight basis

CLADRANG - <u>Cladina rangiferina</u>
CLADSTEL - <u>Cladina stellaria</u>
CLADUNCL - <u>Cladonia uncialis</u>

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	Mo, ppm	Nb, ppm	Nd, ppm	Ni, ppm	Pb, ppm	Sc, ppm	Sr, ppm	V, ppm	Y, ppm	Zn, ppm
CLADRANG-1	<0.1	0.2	0.2	0.4	0.67	0.3	15	3.0	0.4	13
CLADRANG-2	<0.1	<0.1	0.1	1.9	0.53	0.1	11	1.0	0.2	24
CLADRANG-3	0.09	<0.1	0.2	0.4	0.50	0.1	14	1.3	0.2	16
CLADRANG-4	<0.1	<0.2	0.2	0.5	0.67	0.2	12	1.9	0.3	11
CLADRANG-5	0.07	<0.2	<0.2	0.4	0.54	0.2	14	1.5	0.2	16
CLADRANG-7	0.05	<0.1	0.1	0.4	0.58	0.1	10	0.9	0.1	13
CLADRANG-8	0.07	<0.1	0.2	0.5	1.0	0.2	11	1.4	0.2	12
CLADRANG-9	<0.1	0.2	0.2	0.4	0.52	0.2	14	2.0	0.3	13
CLADRANG-10	<0.1	<0.1	0.2	0.4	0.63	0.1	11	1.3	0.2	11
CLADRANG-11	0.08	<0.1	0.1	0.4	0.71	0.1	10	1.3	0.2	7
CLADSTEL-1	0.05	<0.1	0.1	0.3	0.54	0.1	10	1.0	0.2	13
CLADSTEL-2	0.05	<0.1	<0.1	0.9	0.60	0.1	11	0.9	0.2	14
CLADSTEL-3	0.05	<0.1	0.1	0.6	1.1	0.1	10	1.0	0.2	14
CLADSTEL-4	0.05	<0.1	0.2	0.7	0.67	0.1	9	0.9	0.2	11
CLADSTEL-5	<0.1	<0.1	0.1	0.3	0.47	0.1	10	0.8	0.2	15
CLADSTEL-7	<0.1	0.1	0.2	0.4	0.58	0.2	9	1.6	0.3	11
CLADSTEL-8	<0.1	<0.1	0.1	0.2	0.67	0.1	7	0.[illegible]	0.1	10
CLADSTEL-9	0.05	<0.1	0.1	0.3	0.72	0.1	8	0.6	0.1	9
CLADSTEL-10	<0.1	<0.1	0.3	0.4	1.3	0.2	13	1.3	0.3	14
CLADSTEL-11	0.06	<0.1	0.1	0.3	0.54	0.1	10	0.9	0.2	14
CLADUNCL-1	<0.1	0.1	0.1	0.5	1.0	0.1	10	1.1	0.2	11
CLADUNCL-2	<0.1	<0.1	0.1	0.3	0.69	0.1	10	0.9	0.2	12
CLADUNCL-3	0.06	<0.1	0.1	0.4	0.66	0.1	11	0.8	0.1	19
CLADUNCL-4	<0.1	<0.1	0.1	0.3	0.50	0.1	10	1.0	0.2	11
CLADUNCL-5	<0.1	<0.1	0.1	0.8	0.85	0.1	13	1.3	0.2	21
CLADUNCL-7	<0.1	<0.1	0.1	0.4	1.0	0.1	10	1.1	0.2	12
CLADUNCL-8	<0.1	<0.1	0.2	0.8	0.82	0.1	11	1.2	0.2	17
CLADUNCL-9	0.15	<0.1	<0.1	0.6	0.80	0.1	20	0.9	0.2	18
CLADUNCL-10	<0.1	<0.1	0.2	1.7	0.90	0.2	12	1.6	0.3	18
CLADUNCL-11	0.12	<0.1	0.1	0.8	1.0	0.1	11	0.6	0.1	9

* ppm dry-weight basis

CLADRANG - *Cladina rangiferina*
CLADSTEL - *Cladina stellaria*
CLADUNCL - *Cladonia uncialis*

Appendix C. Elemental concentrations in lichen samples from Chisik Island, June 1993.*

Sample ID	Mn, ppm	Ba, ppm	Cd, ppm	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Ga, ppm	La, ppm	Li, ppm
CLADRANG-1	49	13	<0.1	0.5	0.4	0.67	3.2	0.4	0.4	0.4
CLADRANG-2	72	7	<0.1	0.3	0.2	0.41	3.1	0.2	0.2	0.2
CLADRANG-3	45	9	<0.1	0.3	0.2	0.38	3.3	0.2	0.2	0.3
CLADRANG-4	41	11	<0.1	0.4	0.2	0.54	2.4	0.3	0.3	0.3
CLADRANG-5	52	11	<0.1	0.4	0.2	0.41	3.4	0.3	0.2	0.3
CLADRANG-7	31	8	<0.1	0.2	0.1	0.35	2.8	0.2	0.2	0.2
CLADRANG-8	16	10	<0.1	0.4	0.2	0.51	2.5	0.2	0.2	0.3
CLADRANG-9	43	14	<0.1	0.4	0.3	0.52	2.9	0.3	0.3	0.3
CLADRANG-10	28	10	<0.1	0.3	0.2	0.40	2.5	0.2	0.2	0.2
CLADRANG-11	29	9	<0.1	0.3	0.2	0.51	2.0	0.2	0.2	0.2
CLADSTEL-1	44	6	<0.1	0.3	0.2	0.34	2.4	0.2	0.2	0.2
CLADSTEL-2	47	6	<0.1	0.3	0.2	0.37	2.8	0.1	0.2	0.2
CLADSTEL-3	31	6	<0.1	0.2	0.1	0.32	2.5	0.1	0.2	0.2
CLADSTEL-4	25	6	0.05	0.3	0.2	0.32	3.7	0.1	0.2	0.2
CLADSTEL-5	50	6	<0.1	0.2	0.1	0.31	2.9	0.1	0.1	0.2
CLADSTEL-7	27	10	<0.1	0.4	0.2	0.42	2.4	0.2	0.3	0.3
CLADSTEL-8	21	5	<0.1	0.2	0.1	0.22	2.5	0.1	0.1	0.1
CLADSTEL-9	17	5	0.05	0.2	0.1	0.26	3.1	0.1	0.1	0.1
CLADSTEL-10	21	10	<0.1	0.5	0.2	0.43	3.2	0.2	0.3	0.2
CLADSTEL-11	28	7	<0.1	0.3	0.1	0.40	3.2	0.1	0.2	0.2
CLADUNCL-1	31	6	<0.1	0.3	0.2	0.36	2.0	0.1	0.2	0.2
CLADUNCL-2	37	7	<0.1	0.2	0.1	0.33	7.0	0.1	0.2	0.2
CLADUNCL-3	29	6	<0.1	0.2	0.1	0.32	7.1	0.1	0.1	0.2
CLADUNCL-4	34	7	<0.1	0.3	0.1	0.33	3.8	0.1	0.2	0.2
CLADUNCL-5	42	8	<0.1	0.3	0.2	0.48	2.9	0.2	0.2	0.3
CLADUNCL-7	25	8	<0.1	0.3	0.2	0.36	2.8	0.2	0.2	0.2
CLADUNCL-8	21	8	<0.1	0.3	0.2	0.40	2.5	0.2	0.2	0.2
CLADUNCL-9	17	9	<0.1	0.2	0.2	0.35	4.0	0.1	0.2	0.2
CLADUNCL-10	32	11	<0.1	0.4	0.2	0.52	3.0	0.2	0.2	0.3
CLADUNCL-11	27	6	<0.1	0.2	0.1	0.26	8.7	0.1	0.1	0.2

* ppm dry-weight basis

CLADRANG - <u>Cladina rangiferina</u>
CLADSTEL - <u>Cladina stellaria</u>
CLADUNCL - <u>Cladonia unicialis</u>

Appendix D

Semipermeable Membrane Devices
Summary Report.

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TESTING METHOD/PROTOCOLS REQUIRED FOR THE CONTAMINANT ASSESSMENT AREA PROCESS - AIR QUALITY MONITORING TECHNIQUES IN THE ALASKA MARITIME, NATIONAL WILDLIFE REFUGES TUXEDNI WILDERNESS AREA

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INTRODUCTION

An integral part of the National Biological Survey's (NBS) ecological based research program is the need to identify and evaluate the route of anthropogenic contaminant transport. The Biomonitoring of Environmental Status and Trends (BEST) Program is the primary focus within NBS for conducting field studies designed to address the potential routes of contaminant transport. The current research effort was undertaken to determine the potential for airborne contamination to impact isolated areas in Alaska.

The semipermeable membrane devices (SPMD) technology has been demonstrated to hold considerable promise for providing time-integrated concentrations of nonionic organic contaminants in aquatic environments, and for estimating the bioavailability and potential bioconcentration of such contaminants, (Huckins, et. al., 1990, 1993). The feasibility of the SPMD approach for monitoring airborne contaminants also appears promising (Petty, et.al., 1993), as the SPMDs mimic the uptake of contaminants via the respiration process.

In an effort to demonstrate the feasibility of the SPMD approach for use in monitoring airborne contaminants, the devices were deployed in the Alaska Maritime National Wildlife Refuges Tuxedni Wilderness area (specifically Chisik Island). The Tuxedni Wilderness is a class I air quality area and is consequently subject to stringent air quality standards (Clean Air Act, 42 U.S. Code 7401 et seg.). As a positive control, SPMDs were deployed in metropolitan Anchorage. Presented below are the results of the analysis of the SPMDs used in this research effort.

RESULTS AND DISCUSSION

Quality Control:

The SPMDs (N=5) were deployed on Chisik Island and Anchorage Alaska during June and July, 1993. Following retrieval, the SPMDs were shipped to the Midwest Science Center (MSC). The SPMDs were processed as previously described (Petty, et.al., 1993), and forwarded to the Patuxent Analytical Control Facility for analysis. As part of the quality control procedures, we shipped two performance evaluation materials (PEM) (blind samples) as part of the sample catalogue. These PEMs consisted of 30 ug of each priority pollutant PAH in 5mL of hexane and 10 ug of Aroclor® 1242, 1248, 1254, and 1260 in 5 mL of hexane. The results of the analysis of these PEMs by the contract laboratory are presented in Tables 1 and 2. In general, the results are quite good. The value for aroclor 1248 is somewhat high (130% recovery) but still acceptable. In the case of the PAHs, the reported values are acceptable.

In addition to the PEMs, field blanks (one for each site), a laboratory process blank, and an SPMD control were provided as part of the sample set. With the exception of HCB which is a MSC laboratory contaminant, no blank sample contained residue greater than the stated detection limits of the contract laboratory (i.e. 0.25 ug/g for PAHs and 0.004 ug/g for PCBs and OCs).

Based upon the results of the analysis of PEMs and the blanks, we believe the samples were deployed, retrieved, processed, and analyzed without introducing extraneous contamination. Consequently, the SPMD sample data appear to be representative and acceptable.

__SPMD Samples__:

The analysis of the 5 SPMD samples from Chisik Island revealed anthropogenetic contaminants to be present in only one sample. The residues; benzo(a)pyrene (0.35 ug), benzo(b)fluoranthene (0.28 ug), benzo(e)pyrene (0.30 ug), benzo(k)fluoranthene (0.30 ug), and perylene (0.39 ug) were all very low and near the stated detection limit. Further, only one of 5 samples contained detectable residues. Consequently, the Chisik Island site does not appear to have been impacted by PAHs or other anthropogenic contaminants during the exposure period.

The results of the analysis of SPMDs deployed at the Anchorage site are presented in Table 3. In contrast to the Chisik Island site, contaminant residues were present in all 5 SPMD samplers. Alpha-BHC and gamma-BHC were present in 4 of 5 samplers with a mean value of 0.010 ug/SPMD and 0.017 ug/SPMD, respectively. No PCB residues were detected in these samples. The PAH values presented in Table 3 are somewhat variable (RSD ranging from 24 to 37%) but appear to be verify the presence of PAH residues. Moreover, the residue found in these SPMDs are indicative of bioavailable residues (i.e. by respiration).

CONCLUSIONS

The data from this study demonstrate the utility of SPMDs to sequester airborne anthropogenic contaminants. Further, the SPMDs were successfully used to define the absence of detectable airborne contaminants on Chisik Island and the presence of typical anthropogenic contaminants in the air at the Anchorage site. Thus, the SPMD technique can be employed in ambient air monitoring activities.

Further research is required to develop the algorithm(s) necessary to estimate actual air concentrations. This research would involve controlled laboratory studies to define the kinetics of uptake of contaminants by SPMDs and additional field deployment of the SPMDs.

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Table 1

PAH	Recovery of Priority Pollutant Polycyclic Aromatic Hydrocarbons - Performance Evaluation Material		
	Spike Level (ug/SPMD)	Recovery (ug/SPMD)	(%)
Naphthalene	30	21	70
Acenaphthglene	30	29	97
Acenaphthene	30	24	80
Fluorene	30	26	87
Phenanthrene	30	24	80
Anthacene	30	26	87
Fluoranthene	30	22	73
Pyrene	30	26	87
Benz(a)anthracene	30	NA[1]	NA
Chrysene	30	22	73
benzo(b)fluoranthene	30	28	93
Benzo(k)fluoranthene	30	27	90
Benzo(a)pyrene	30	28	93
Indeno(1,2,3,-c,d)pyrene	30	NA	NA
Dibenz(a,h)anthracene	30	22	73
Benzo(g,h,i)perylene	30	19	63

[1] NA = Component not analyzed for in sample.

Table 2

PCB	Recovery of Polychorinated Biphenyls - Performance Evaluation Material		
	Spike Level (ug/SPMD)	Recovery (ug/SPMD)	(%)
1242	10	9.9	99
1248	10	13	130
1254	10	12	120
1260	10	9.3	93

Table 3

Analyte	Residues Found in SPMDs From Positive Contaol Site ug/SPMD[1]							
	Site 1 - 1	Site 1 - 2	Site 1 - 3	Site 1 - 4	Site 1 - 5	X	S,D	RSD (%)
Dibenz(a,h)anthracene	<0.25	<0.25	<0.25	0.30	0.39	0.34	---	---
Alpha - BHC	0.009	<0.004	0.012	0.010	0.009	0.010	0.0014	14
Benzo(a)pyrene	<0.25	0.34	0.45	0.60	0.58	0.49	0.12	24
Benzo(b)fluoranthene	0.30	0.35	0.49	0.50	0.60	0.45	0.12	27
Benzo(e)pyrene	<0.25	<0.25	0.29	0.35	0.50	0.38	0.11	29
Benzo(k)fluoranthene	<0.25	0.30	0.47	0.35	0.63	0.44	0.15	34
Fluorene	<0.25	<0.25	<0.25	<0.25	0.30	0.30	---	---
Gamma - BHC	0.015	<0.004	0.018	0.015	0.018	0.017	0.0017	10
Perylene	<0.25	<0.25	0.53	0.72	1.1	0.78	0.29	37

SPMD = 34 inches of polyethylent layflat tubing containing 1.0 mL triolein; 4.1 grams